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A STUDY OF THE COMPUTATIONAL REQUIREMENTS FOR SPARES IN THE USA--ETC(U)

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(10) William M. Aven Captain, USAF
Donald R. Root 2nd Lieutenant, USAF

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The Spares Acquisition Integrated with Production (SAIP) program is a concept designed for acquiring initial and follow-on spare parts for new weapon systems concurrent with production. SAIP offers a spares ordering technique which can aid in the problem of maintaining operational readiness while remaining within budgetary guidelines. SAIP program application can be enhanced by standardizing the computational method for estimating the spares required on new systems. This research effort explores the current methods of computation requirements in the SAIP program as applied on the A-10 aircraft. A recommendation is made concerning the method which is found statistically more accurate in predicting spares demand for this weapon system. By employing the most accurate method for computation requirements, operational readiness of new weapon systems can be enhanced while investment, inventory, and obsolescence costs are not abused.

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A STUDY OF THE COMPUTATIONAL REQUIREMENTS FOR SPARES IN THE USAF A-10 SAIP PROGRAM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

William M. Aven, BBA
Captain, USAF

Donald R. Root, BS
2nd Lieutenant, USAF

June 1980

This thesis, written by

Captain William M. Aven

and

2nd Lieutenant Donald R. Root

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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Joe B. Knowles
COMMITTEE CHAIRMAN

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GLOSSARY OF ACRONYMS

AFLC	Air Force Logistics Command
AFPRO	Air Force Plant Representative Office
AFSC	Air Force Systems Command
ALC	Air Logistics Center
ASD	Aeronautical Systems Division
ALD	Acquisition Logistics Division
CAS	Close Air Support
DOD	Department of Defense
FY	Fiscal Year
GD	General Dynamics
HQ	Headquarters
ILDF	Integrated Logistics Data File
IM	Item Manager
LRU	Line Replaceable Unit
McAir	McDonnell Douglas Corporation
MTBF	Mean Time Between Failure
NMCS	Not Mission Capable Supply
NSN	National Stock Number
NSPL	Negotiated Spare Parts List
NRTS	Not Repairable This Station
NTE	Not To Exceed

PMC	Procurement Method Code
SAIP	Spares Acquisition Integrated with Production
SM	System Manager
SPO	Systems Program Office
SPSS	Statistical Package for the Social Sciences
SRU	Shop Replaceable Unit
USAF	United States Air Force
WRM	War Readiness Material

Chapter 1

INTRODUCTION

Overview

The Spares Acquisition Integrated with Production (SAIP) program is a relatively new concept designed for acquiring initial and follow-on spare parts support for new United States Air Force (USAF) weapon systems. The SAIP procedure is intended to obtain initial and replenishment spares from production installation at the least cost to the U.S. Government (21:1). An initial spare is an item procured for logistics support of a weapon system during its initial period of operation; a replenishment spare is an item procured for logistics support after provisioning (21:1). Conceptually, SAIP holds down the cost of spares by avoiding the costs associated with separate material orders and manufacturing actions which could result if spares and items for production installation were not ordered and managed together. The SAIP concept is based on the general principle that spares costs can be reduced if separate production set up and special acceptance and test procedures for the spares can be avoided by the contractor. Five basic SAIP principles are essential for successful implementation. First of all, concurrent ordering and release of initial spare

parts with installed orders is essential. Firm prices or Not To Exceed (NTE) prices must be negotiated. Initial spares must meet current configuration changes on the aircraft. Also, firm order quantities to the vendor are necessary; and finally, the SAIP concept should be applied to any new production program estimated to cost $300 million or more and any modification program estimated to cost $100 million or more which requires initial spares support (23:3).

Initial provisioning for USAF tactical aircraft is a large business involving a significant percentage of the Air Force portion of the Department of Defense (DOD) budget. During FY 1977, USAF procurement agencies committed more than $769 million on initial provisioning with an additional $750 million budgeted for FY 1978 (12:1). SAIP techniques were used to procure $470 million in weapons spares during FY 1977 (13:6). The magnitude of the annual dollar investment and the effect of provisioning on operational readiness make this area of spare parts acquisition a primary concern for all levels of DOD. It is imperative in these times of increased fiscal constraint and limited budgets, that defense dollars be utilized and expended in such a way as to maximize the usefulness of the purchase.

The SAIP technique has been in existence since 1974, and has been applied to three weapon system acquisitions, with somewhat less than full success. The attempted applications of the SAIP program were directed toward spares procurement for the McDonnell

Douglas F-15, General Dynamics F-16, and Fairchild Republic A-10 aircraft. The SAIP application to these three programs was "less than successful because generally, the comprehensive, step by step procedures required for proper program implementation were not followed (13:8)." Improper implementation was due to many and various reasons.

The F-15 program marked the beginning of the SAIP technique in the USAF. SAIP was not developed by the USAF but actually by the McDonnell Douglas Corporation (McAir). In anticipation of increased production buys, McAir developed contractual options with their subvendors to obtain approximately fifty percent more of the quantity of subassemblies originally ordered for the F-15 at production prices. The USAF did not exercise their options for more aircraft so McAir then offered the additional assets as spares to the USAF at a large cost savings. The magnitude of these price breaks led to the conception that initial spares provisioning and replenishment, concurrent with production, could be a tremendous financial success in the system's acquisition process. With this realization, the SAIP concept was applied to two new weapon systems, the F-16 and the A-10.

The F-16 SAIP program began poorly when it was excluded from the production contract because of delays in the initial approval of the SAIP concept. When a separate spares contract was negotiated,

it was tied to the production contract by several clauses which provided for configuration control. This insured validation by the prime contractor that spares being procured were the same as ones being installed on the F-16 aircraft. Because of the time delay and because the prime contractor, General Dynamics (GD), already had contractual agreements with many of their subvendors, approximately half of the subvendors would not participate (13:8). This in itself severely limited the effectiveness of the program. In addition, because of the involvement of the European participating governments, stability of SAIP order quantities has almost been impossible. Without this stability, the price advantages normally associated with SAIP were not obtained.

The A-10 program utilized more SAIP procured spares than any of the other weapon systems under the same concept. Most of the subvendors participated in the program and the order quantities were stable. Because of War Readiness Material (WRM) procurements and additional buys required for an increased flying hour program, numerous non-SAIP as well as SAIP buys have been made. However, this offered an advantage because a unit price comparison could be made of SAIP versus non-SAIP procured spares. When this comparison was conducted, the determination was that consistently, the SAIP procured items were less costly on a unit basis than the non-SAIP buys (13:12). The A-10 program provides the best example

of the SAIP concept to date.

The SAIP program can purportedly offer advantages to the USAF, and to the vendor as well. Advocates argue that within the USAF, SAIP can reduce spares acquisition cost, ensure timely delivery of properly configured spares, and reduce the Not Mission Capable Supply (NMCS) rates. Within the Air Force Logistics Command (AFLC), advantages include only one contract to monitor for a weapon system, one contractor to measure, reduction in contract negotiation, and centralized procurement. The vendor can also enjoy such advantages as a reduction in number of purchase orders to subcontractors, a drastic reduction in number of production releases, and consolidation of orders to allow for more efficient production planning.

Though the SAIP program has been in existence since 1974, it has recently been heavily criticized in the higher echelons of the U.S. Government, including the Office of the Secretary of Defense (6:1). HQ USAF feels that "an evaluation of on-going programs is valuable to document not only cost effectiveness but also to improve our application of SAIP." Severe criticism of the SAIP program was also extended during the HQ AFLC Inspector General in depth review of SAIP during the week of 12-23 March 1979. The Functional Management report stated:

> Overall implementation of the SAIP concept was UNSATISFACTORY. The lack of policy and procedural guidance coupled with late direction to use SAIP techniques on the A-10 and F-16 aircraft precluded orderly and effective program implementation [17:1].

Problem Statement

Acquisition of spare parts to be delivered at the right time, in the right configuration, in the right quantity and at the lowest cost is an objective of the provisioning process. SAIP is but one spares procurement technique that has been implemented to obtain these benefits. However, SAIP has not yet produced the benefits expected of this type of program. This is evident when one examines the SAIP application on the F-15, F-16, and A-10 aircraft, which in all cases was less than totally successful. This thesis will focus on one problem associated with the SAIP program. This problem concerns the initial requirements computations for SAIP spares to be ordered initially for a new weapon system. The HQ AFLC Inspector General had this comment concerning the SAIP requirements computation process.

> A standard method of computing SAIP recoverable item requirements should be developed. Variations in current approaches could result in unrealistic fill rates and excessive support costs [17:ii].

The specific research of this thesis focuses on the computational requirements methods used in the SAIP program and the accuracy of each.

Literature Review

The weapon systems acquisition process is aimed at the perceived national defense deficiencies of tomorrow and is constantly in competition with obsolescence, inflation, and exploding technology (14:5). Today's acquisition process is expected to seek the most satisfactory compromise between lifetime ownership cost, schedule of achievable deployment and adequate, reasonably attainable performance. But with a typical gestation period of a weapon system being 10 years and where production and deployment may extend this to an additional 15 to 20 years, the acquisition costs may become astronomical. Such costs would include complex demands placed upon the system, multiple missions, extensive testing and production delays.

The requirement for combat readiness of a weapon system generates a need for spare parts to keep it operational. Essentially, one can categorize every single part that compromises an entire aircraft as a spare part. The result of a shortage of spare parts for a system is referred to as a "not mission capable due to supply" (NMCS[1]) condition when the system cannot be used due to the shortage (1:56). NMCS statistics are but one of many statistics that

[1]The term NMCS was originally known as NORS (not operationally ready due to supply). Where NORS is used in this thesis, the term is quoted from a previous study.

measure the effectiveness of a weapon system's logistics support.

When the U.S. Army Signal Corps entered into a contract with Wilbur and Orville Wright for the manufacture and delivery of one heavier-than-air flying machine, the requirement for spare/ repair parts was omitted (22:ii). In sharp contrast, the USAF FY78 budget submission to the Office of the Secretary of Defense included an estimate of over $331 million for initial spare/repair parts to support the Air Force's F-16 Air Combat Fighter Acquisition (18:ii). This amount was budgeted to provide initial spares for a procurement planning total of 1388 aircraft delivered during FY80 through FY87 time period, and is sufficient to procure over thirteen million Wright Flyers in 1908 dollars (7:7). Thus, procurement of spare parts for new weapon systems has evolved into a very costly and a very necessary segment of total systems acquisition.

In 1969 the Logistics Management Institute, sponsored by the Naval Air Systems Command, proposed models for the prepositioning of spare components and parts to speed the rework of aircraft (14:1). At given points in time there existed a significant number of naval aircraft in a nonoperational status undergoing depot level rework. It was proposed that if the time required to rework those aircraft could be reduced, the number of aircraft which were in a nonoperational status could also be reduced. The models are based on a method of measuring the dollar value of the savings which would be

realized when a spare component or part was obtained for this purpose. The ratio of the savings to the cost was developed and used to generate optimum procurement plans and budgets. The dollar value of savings was determined by computing the reduction in aircraft rework time that can be obtained by adding a specific unit of a component to a pool of spares. The expected reduction in rework time was then converted into the quantity and worth of aircraft which would be released from the pipeline to the fleet by adding that specific part.

Further recognition was given to the tremendous importance of spares in support of major weapon systems. In 1975, a thesis by F. Abrams addressed acquisition of spare parts as a major consideration in weapon system planning because of the complexity of the task and the magnitude of the numbers of parts involved (1:55). In a weapon system activation process several important comments addressing problems in this area were observed.

> The unacceptable NORS rate early in FY65 clearly indicated that a proper log in of spares had not been accomplished and the non-availability of spares was the only deterrent to TAC's sustaining the 5775 flying hours quarterly training program in F-4 wings [1:56].

"Ineffective range and depth of spares on the ISSL as well as a lack of timely fills on base requisitions contributed to the NORS problems [1:56]." The history of the 58 Tactical Fighter Wing noted that "the initial spares support log in for the A-7D project at Luke AFB was difficult in many areas. Virtually every part that the A-7D was

NORS for had to be obtained from off base [1:57]." "The major problems encountered in maintaining the A-7D at Luke AFB revolved around a matter of maintaining spare parts for the aircraft [1:57]." "The depot had no definite consumption data on which to buy parts and it was necessary to go to the manufacturer for many parts [1:57]."

The activation of the F-111 series aircraft was no less turbulent in the area of spares availability than its predecessors. The history of the 207 Tactical Fighter Wing points out that there was an austere spares-buy for the program, and hence there were continuous shortages of many critical items (1:58).

Abrams concluded, it was quite apparent that activations of new weapon systems in the Air Force have been plagued with spares problems. He proposed that while a solution resulting in 100% efficiency of spares support was wishful thinking, greater management attention to the spares situation should be able to improve on the dismal performance which had traditionally been recorded.

In 1976, W. Montgomery undertook a study to analyze within the Air Force the impact upon spares acquisition of the Procurement Method Coding (PMC) decision (16:ii). This decision provides codes for spare parts which dictate which method of procurement will be used for a particular spare part. With growing pressures on procurement dollars, the accuracy and effectiveness of decisions regarding how spare parts should be purchased were becoming

increasingly important. The ability to support operational readiness requirements at the lowest possible price consistent with quality requirements was a substantial management issue directly related to the PMC decision. For the Air Force, Air Force Logistics Command has PMC responsibility.

The Air Logistics Centers effected the PMC decision process by means of AFR 57-6, DOD High Dollar Spare Parts Breakout Program Manager, located in the Directorate of Material Management. The Program Manager convened a team of experts on an ad hoc basis to evaluate contractor recommendations and supporting information related to that recommendation. A PMC was assigned dictating the method of purchase usually for the lifetime of the weapon system.

Montgomery concluded his report with criticism of the PMC decision. Substantial budget dollars were hanging in balance as the evaluation of contractor recommended codes was accomplished. This evaluation too frequently excluded participants from the very organization charged with using the parts and with saving procurement dollars. The author felt that these people do know the operational environment, the market place and contractor capabilities best.

With the passage of Air Force Regulation 800-26, the Air

Force formalized the Spares Acquisition Integrated with Production (SAIP) program (21:1). This program accentuated the importance of a need for successful spare parts support for new Air Force weapon systems. Is this SAIP program successful? In March of 1979 the Office of Inspector General at HQ AFLC conducted a functional management inspection of the SAIP program. The purpose of the inspection was to evaluate the implementation of the SAIP program on the A-10, F-15, and F-16 weapon systems. The report concluded that overall implementation of the SAIP concept was unsatisfactory (17:2). The Inspector General did however indicate that the SAIP concept was valid and offered both potential cost savings and weapon system supportability benefits, if implemented effectively by improving the policy and using better procedures.

In summary the previous studies all clearly center upon the extreme importance of spare parts for the successful functioning of a weapon system. Because spare parts are so vital to a weapon system, one must ask how best to purchase those spares? The SAIP program offers an answer to this question. However, up to this point while the SAIP concept has been considered valid in theory, its application through proper implementation in the Air Force has been unsatisfactory. Through research analysis of each aspect of the SAIP program, perhaps a more ideal spares procurement method for

initial and replenishment buys can be formulated. One very critical aspect of the SAIP program is the initial spares requirements computation. This thesis effort focused on the computational requirements methods used in the SAIP program and the accuracy produced by each method. Accuracy in the requirements area is essential to gain the dollar savings associated with use of the SAIP program (17:ii).

Research Objective

The two current computational requirements methods used in the SAIP program for estimating initial spares on new weapon systems were investigated and analyzed. The accuracy of each computational method was determined by utilizing base year spares data for the A-10 aircraft.

Research Questions

In order to achieve the objective of the thesis, the following research questions were developed to guide the effort.

1. What computational methods are utilized in determining initial spare requirements for the SAIP program?

2. What factors within these methods have a direct bearing upon the computed requirements determination?

3. What computational method provides a more accurate estimate of actual demand for spare parts?

Research System Boundaries

The SAIP program has been criticized for numerous deficiencies in its application to new weapon systems. However, this research concentrated on only one SAIP documented problem, that of initial requirements standardization in order to avoid unrealistic fill rates and excessive support costs.

Overview of Remaining Chapters

Chapter 2 contains an overview of the two computational requirements programs used for the SAIP concept.

Chapter 3 presents the research methodology employed to examine the SAIP initial requirements computations problem.

Chapter 4 presents findings, conclusions and discussions in addition to SAIP program recommendations concerning the initial requirements methodology.

Chapter 2

COMPUTATIONAL REQUIREMENTS PROGRAMS

Introduction

The SAIP program has as its ultimate objective the purchasing of selected initial and replenishment spare parts at the same price as identical items to be installed in the system or end item. This price benefit is achieved by ordering the spare items concurrently with identical installed items. The lower price is the result of avoidance of separate set-up charges, and avoidance of special acceptance and test procedures for the spares by the contractor. Concurrent ordering requires the cooperation of the contractor, the systems acquisition procurement office and the prime ALC.

SAIP item candidates are first recommended by the contractor at least 165 days prior to the SAIP order release date. The contractor recommends to the SM a range and quantity of items suitable for SAIP. The SM then, in turn, is responsible for coding the recommended items as SAIP program potential items and also for identifying the items to be processed under SAIP procedures well in advance of the projected order date for the identical installed

items. The long lead time release date is the most logical order date for SAIP items since most SAIP items are long lead time items.

On or before the 120th day prior to the SAIP order release date, the IM/SM will furnish the contractor, through the AFPRO, a list of approved SAIP items, quantities, and desired delivery schedules. The IM has performed the computational requirements function, initiated cataloging and standardization actions in order to compile the approved SAIP list for the contractor. If the SAIP item candidate is a newly engineered part without any historical data in the USAF, the IM must rely on contractor furnished data to complete the requirements computations. Contractor data may or may not be totally accurate--it is his best estimate from engineering data generated at his own plant. If the SAIP item has been used in the USAF inventory before, the IM has available historical data for use in the computational formulas. No changes in items or designated quantities will be permitted after the SAIP list has been submitted to the contractor except in the case of a major program change (2). The importance of accurate requirements computations is readily apparent.

Data and Method of Study

For the purpose of this research effort, the actual demands for A-10 SAIP items in the first operational year were statistically analyzed against theoretically recommended SAIP buys using the two

acceptable requirements techniques, MODMETRIC and "57-27." To do this, several categories of historical data relevant to both methods were required. The categories included:

1. Historical demand data at both base and depot level.
2. Order and ship time.
3. Flying hour programs.
4. Repair cycle times and engineering data.
5. Production and administrative lead time.
6. NRTS and condemnation rates.

A complete listing of all SAIP items for the A-10 aircraft was extracted from the ILDF located at the A-10 SPO. This provided a potential base of 167 NSNs to utilize in analyzing the initial requirements computation methods. However, in searching the D041 Depot Data Bank using type "01" and "50" type records, only 47 NSNs had complete historical information concerning the initial operational year of the A-10 weapon system. The "01" and "50" type records are data files within the D041 that contain certain descriptive requirements data that may be recalled.

To determine the flying hour program for the A-10, historical data was collected from the G033 report, System Flying Hours, for the initial operational year. This provided the required information to use in the two computational formulas to predict the needed SAIP spares. Two computational methods currently exist for estimating initial spares requirements within the SAIP program. These

two methods are employed by the individual item managers (IM) at their respective Air Logistics Centers (ALC). The "57-27" method, so named because it is governed by AFLC Regulation 57-27. is an initial requirements computational procedure for estimating expense, investment, and equipment items (20). MODMETRIC, a Modification of the Multi-Echelon Technique for Recoverable Item Control (METRIC) technique, is a computer program developed by the RAND Corporation and adopted for use by the USAF for estimating initial and replenishment spares (15).

Before discussion of the two computational methods, the relationships of line replaceable units (LRU) to shop replaceable units (SRU) must be explained. The SAIP program is predicated on the assumption that concurrent ordering of high cost spares with production will result ultimately, over the life cycle of a weapon system, in a large dollar savings. Items selected for SAIP are high cost recoverable items and represent between 65 and 75% of the initial spares investment and only 5% of the items for a new weapon system (4:6). Typically, these high cost spares are LRUs and SRUs. These items are those which may be repaired on failure and thus returned to a serviceable condition. Approximately 170,000 National Stock Numbers (NSN) with inventories in excess of $5 billion fall into this category in the USAF (4:12). This obviously represents a very

significant inventory cost and the need for accurate procurement and careful management is of paramount importance.

In general, SAIP recoverable items are supported by a two echelon inventory/repair system. When a weapon system is first added to the AF inventory, initial provisioning includes procurement of a number of serviceable spares to support the new weapon system. These spares are then dispersed to the appropriate base locations to provide on-site support for operating forces. Depot supply also maintains serviceable spares, both to support depot repair activities and to provide a backup source of supply for bases with unusually high demand requirements.

When a recoverable item fails at base level, it is turned in to base supply and a new serviceable unit is issued. The base maintenance function attempts to repair the item and if successful returns the unit to base supply. If unsuccessful, the failed item must be returned to the depot where more sophisticated equipment and specialized skills are available. In this situation, the base submits a requisition to the depot supply organization to obtain a serviceable replacement for the failed item. The depot then attempts to fill the requisition. If serviceable units are available at the depot, the requisition is immediately filled. Otherwise, with SAIP items, the unit must be specially ordered from the contractor, with an accompanying long back order time incurred. Occasionally, failed

items cannot be economically repaired. When this is the case, the item is condemned and the IM either determines to place an order for a replacement or operate with one less spare asset.

LRU/SRU Relationship

Many modern weapon systems are built on a modular basis. LRU is the term used to describe a major assembly that may be removed and replaced on an aircraft at the flight line. If a failed LRU cannot be repaired at the base level, the faulty unit would be forwarded to the depot. Otherwise, the LRU is moved to a base maintenance shop for repair. Repair of these modularly designed systems often consists of the removal and replacement of one or more of its components, or modules. These components are the SRUs. SRUs comprise the second level of indenture in the parts hierarchy of the aircraft. If the SRU cannot be repaired at the base, the failed SRU is either condemned or shipped to the depot. Otherwise, base maintenance personnel attempt to repair the SRU. The activities of disassembly, removal and replacement continue until the faulty unit is identified and corrected. Similar activities are also performed at the depot level to return failed LRUs and SRUs to a serviceable condition. This two level-of-indenture system is utilized by the logistics support system for USAF recoverable items.

Analytical Models

Several mathematical models have been developed to assist in the management of AFLC recoverable items. Each model differs in terms of the underlying assumptions of the model, the objective function to be optimized, the mathematical optimization procedures used to find "optimal" solutions and computational shortcuts utilized to reduce the computational resources required to obtain solutions.

"57-27" Method

AFLC Regulation 57-27 provides the logic and describes the rules to be used in the computation of initial requirements for expense, investment, and equipment items. Use of this method by IMs was essentially a hand calculated approach utilizing AFLC Form 614 as documentation (see Appendix A). However, recently, the "57-27" method was programmed in FORTRAN computer language and now exists as a subroutine on the CREATE system at AFLC Headquarters. This greatly reduces the workload involved in the hand calculation method and provides a simplified method of the original version. The "57-27" method is essentially based on the assumption that all item parameters such as failure rates, base repair factors, and condemnation rates are known with certainty, and there is no variability of demand. The policy involved with this method is to achieve maximum initial support with available resources, peace time initial spares,

and repair parts to reduce supply response time to allow for an adequate range and depth of spares stockage. Additionally, all acquisition programs must consider the design stability of a system and its impact on logistics cost and risk as well as operational factors in planning the initial phase of operation capability and logistics support. The "57-27" model sets the initial provisioning requirement equal to the amount of stock required to fill the repair/resupply pipeline, that is, the amount of stock which has failed and is either in unserviceable condition and undergoing repair or which has been condemned and is in the process of being replaced by replenishment procurement.

METRIC

In 1968 Rand Corporation developed the METRIC model (Multi-Echelon Technique for Recoverable Item Control) as a tool for managing Air Force recoverable item inventories. This single level-of-indenture technique provides a methodology for computing stock levels in a two echelon inventory/repair system consisting of a depot and possibly several bases. METRIC is utilized in seeking base and depot stock levels which minimize total expected base level back orders summed across all items in the system subject to an investment constraint. In METRIC, no penalty is directly assessed for depot back orders. Depot back orders are considered only in so far as they influence base back orders.

Data elements which are required as input parameters to the METRIC model include the average base and depot repair times for each item, unit cost, not repairable this station (NRTS) rates, and average order and ship times. In addition, the following assumptions are made:

1. A stationary, compound Poisson probability distribution describes the demand process for each item.

2. There is no lateral resupply between bases.

3. There are no condemnations (all failed parts are repaired), nor are there any other gains or losses of assets to the system.

4. A failure of one type of item is statistically independent of those that occur for any other type of item.

5. Repair times are statistically independent.

6. There is no batching of items or other scheduling delays before repair is started on an item.

7. The level at which repair is performed depends only on the complexity of the repair.

8. All demand rates, NRTS rates, and other parameters required by the model are assumed known with certainty.

9. Items and bases may have different essentialities: however all items at a given base are considered to be equally essential (4:12).

Like the "57-27" model, the METRIC model computes a set of base stock levels and depot stock levels, which are consistent with a given investment constraint when used in this form, the model can be used to determine the number of assets that should be procured to operate the system to support a given flying program (20).

MODMETRIC

MODMETRIC is a two level-of-indenture extension of the METRIC concept. The objective of MODMETRIC is to determine the base and depot stock levels which minimize total expected base level back orders for a specific set of items and bases subject to an investment constraint (11, 1-2). The MODMETRIC model extends the METRIC model to include a hierarchal or indentured parts structure. The model permits two levels of parts to be considered, an assembly and its components (15).

The METRIC model assumes the back order of one item is equally undesirable with a back order with any other item. However, with the increased frequency of modular designs in today's weapon systems, the assumption of all back orders being equally undesirable is not a good approximation. With a back order for a line replaceable unit (LRU) an aircraft can either be less mission capable or become grounded. On the other hand, back orders for shop replaceable units (SRU) result in delays in repairing the associated LRU.

Prolonged back orders for SRUs result in LRU back orders and inoperable aircraft; however, this effect is usually not immediate. A diagram of the repair and inventory systems for a modularized LRU is given in Figure 1 (11, 1-4). In short, LRUs are used to repair aircraft while SRUs are used to repair LRUs. The MODMETRIC technique explicitly considers this LRU-SRU relationship and computes the effect of the SRU stock level on the availability of LRUs. Specifically, in MODMETRIC it is assumed that no more than one SRU failure causes the failure of the LRU (5).

In METRIC, the objective is to minimize the expected base back orders over all items (both LRUs and SRUs) subject to an investment constraint; in MODMETRIC, the objective is to minimize the expected base back orders of LRUs subject to an investment constraint on the total dollars allocated to both the LRU and its components. In MODMETRIC, assumptions 2 through 8 of the METRIC model are assumed to hold. The major difference lies where METRIC ignores any relationships among items, while MODMETRIC explicitly considers LRU/SRU relationships. A second major difference between METRIC and MODMETRIC models concerns the METRIC assumption of the stationary, compound Poisson probability distribution of demand (assumption 1) which is replaced by the assumption that demand obeys a simple Poisson process whose mean, M, is an unknown random variable. The prior probability distribution of this

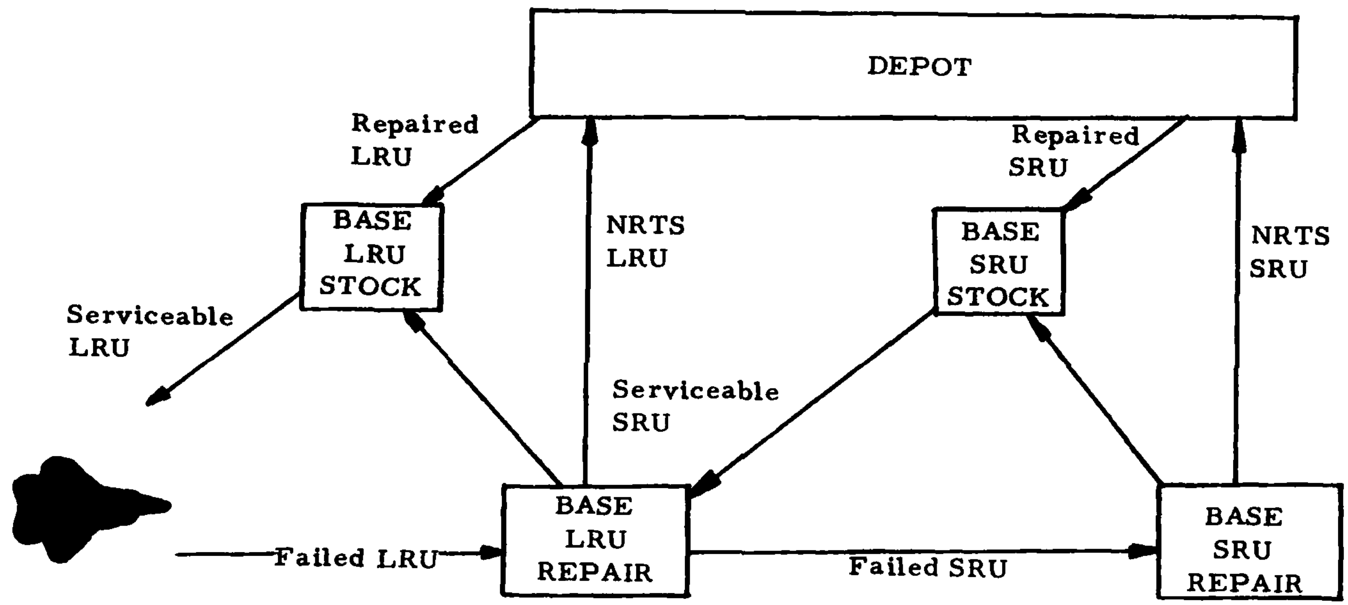

Figure 1. Flow Diagram of LRUs-SRUs

mean M is assumed to be Gamma distributed (11:8).

Thus, MODMETRIC provides a more detailed description of Air Force recoverable item part relationships than is provided by the METRIC model.

Thus far, two computational requirements programs used for the SAIP concept have been examined, the "57-27" method and the MODMETRIC method. In doing so, several categories of historical data relevant to both methods were discussed, particularly the LRU/SRU relationships. Observations show that the MODMETRIC method provides more detail over the METRIC and "57-27" methods since it considers LRU/SRU relationships.

In the next chapter the method of research is presented whereby these two methods of determining initial spares requirements are examined.

Chapter 3

RESEARCH METHODOLOGY

Approach to the Problem

The purpose of this chapter is to describe the research techniques which were used to answer the research questions previously presented. The general approach included five stages. Initially, the background of the SAIP program was introduced and some deficiencies associated with the SAIP technique of acquisition were presented. In the problem statement, the scope of the project was narrowed to focus on one of these deficiencies, a standard method of computing SAIP recoverable item requirements.

Two methods of computation are currently utilized for SAIP spares estimates: the MODMETRIC and the "57-27" method (9). Both methods are described below in detail. The historical deficiencies associated with SAIP were accumulated from Acquisition Logistics Division's (ALD's) Lessons Learned Program and from management reports (unpublished) in the SAIP program monitor office, HQ AFLC/LO.

The second stage of the research effort focused on the computational requirements problem of a specific weapon system, the A-10 aircraft. Out of a total of 167 SAIP spares installed on the

A-10, a total of 47 National Stock Numbers (NSNs) that still retained the historical data needed for this data analysis effort were obtained. Historical data for the remaining 120 NSNs had been erased or deleted from the DO-41 Depot Data Bank listing through either constant interrogation of the magnetic tapes or through operator carelessness (3). It was believed that 47 NSNs which comprised 28% of the population would provide a representative overview of the entire spectrum of SAIP spares for this weapon system. NSNs were extracted from the Integrated Logistics Data File (ILDF) located at the A-10 Systems Program Office.

The next stage of research involved extracting the computational data factors used in the requirements process fcr SAIP items from the DO-41 Depot Data Bank listing. The DO-41 listing is used extensively in requirements analysis. The base year utilized for this analysis was 1974, because it was the first operational flying year for the A-10 aircraft (19). Although SAIP is used for spares replenishment, it is concerned primarily with the initial provisioning of spares and thus the first operational year for the A-10 was chosen as the base period for analysis of SAIP provisioning. In addition to the computational factors utilized, the actual demand data or number of direct demands for those selected SAIP NSNs was also retrieved and recorded.

The computational requirements process for SAIP items on

the A-10 for the base year 1974 were then recreated and extended forward for 20 months. An intensive examination covering a 20 month period was necessary to accurately access the entire SAIP initial requirements period, which because of its long lead time characteristics, covers a period of time greater than the normal one year period. The method involved processing all 47 SAIP NSNs through both the MODMETRIC and AFLCR 57-27 computational programs. These are the programs currently used to determine spares requirements for SAIP items. Identical historical factor data such as order and ship time (OST), flying hours, not repairable this station (NRTS) time, repair cycle time, and production lead time were used in each program. The purpose of processing both computational formulas using identical data was to detect which formula more closely predicted the spares requirements as actually demanded during the first 20 months of the A-10's operational flying program.

Data

The testing for the statistical significance of the gathered A-10 computed data involved setting the data into a specific format. This format was accomplished by taking the difference of the MODMETRIC estimated requirement and the demand function and comparing it to the difference of "57-27" and the demand function.

M_1 = (MODMETRIC) - Demand Function = "MODMET"

M_2 = (57-27) - Demand Function = "57-27"

Types of Tests

There are two general classes of significance tests--the parametric and nonparametric. The parametric tests are more powerful and are generally the tests of choice if their assumptions are reasonably met (8:380). Use of the t-test and the F-test are based on the following assumptions:

1. The observations must be independent. That is, the selection of any one case should not affect the chances for any other case to be included in the sample.

2. The observations should be drawn from normally distributed populations.

3. These populations should have equal variances.

4. The measurement scales should be at least interval, so that arithmetic operations can be used with them.

Nonparametric tests have fewer and less stringent assumptions. They do not specify normally distributed populations or homogeneity of variance. Nonparametric tests are utilized with nominal and ordinal data, and while they may be used for interval and ratio data they tend to waste some of the information available.

What Test to Use?

In attempting to choose a particular significance test, the following three questions were considered:

1. Does the test involve one sample, two samples, or K samples?

2. If two samples or K samples, are the individual cases independent or related?

3. Is the measurement scale nominal, ordinal, interval, or ratio?

In assessing the data, due to the presence of equality of intervals (changes in one method can be equated with changes on the other method), the measurement scale was determined to be of interval level. The data elements were considered independent because they were devised by using two different requirements computational methods. The data sets "MODMET" and "57-27" can be examined in Appendix B.

Determination of Normality

In answer to the question of whether the distributions were normal or not, a Goodness of Fit test was required. For this task the Kolmogorov-Smirnov (K-S) Goodness of Fit test was chosen because the data are interval measured, and the interest was to compare an observed distribution with a theoretical one. Under these conditions the K-S test is more powerful than the Chi-Square test (8:385). Data

sets for each computational method, "MODMET" and "57-27" was run using SPSS program Kolmogorov-Smirnov (K-S) Goodness of Fit test (normal). The test was conducted as follows:

1. Hypothesis: H_o: Distribution is normal

   H_1: Distribution is not normal

2. Significance Level = .10

3. Compare K-S Z statistic to critical value of D in K-S one-sample test.

The results of this test will show whether the distributions of the data sets are normal. See Appendices D, E, and F.

Differences Between Means

Since it is often impossible, and usually impractical, to compute a group mean based on all members of the group, the researchers must use a sample. The true but unknown mean for a group is called the population mean; it is estimated by the sample mean. The comparison of two group means is thus a problem of comparison of two sample means, and from that, inferring the difference between the means of the parent populations.

The basic problem is to determine whether or not a difference between two samples implies a true difference in the parent populations.

Since it is highly probable that two samples from the same

population would be different due to the natural variability in the population, it is clear that a difference in sample means does not necessarily imply that the populations from which they were drawn actually differ on the characteristic being studied.

The goal of the statistical analysis is to establish whether or not a difference between two samples is significant. "Significant" here does not mean "important"; it is used here to mean "signifying" a true difference between the two populations.

Analyzing the difference between means the t-test was chosen because the data were at least interval in form and the samples were independent. The SPSS program t-test (independent samples) was run on "MODMET" and "57-27" data (see Appendix G).

The following procedure was utilized in this analysis:

1. Hypothesis: H_o: $\mu_1 > \mu_2$ $\quad \mu_1$ = MODMET

   H_1: $\mu_1 \leq \mu_2$ $\quad \mu_2$ = 57-27
2. Significance Level: $\alpha = .10$
3. Find t-probability (two-tailed)
4. Find t-probability (one-tailed) by dividing 3. value by two
5. Decision Rule:

   If: one tailed probability $> \alpha$, then accept H_o.

   If: one-tailed probability $\leq \alpha$, then fail to accept H_o.

<u>Analysis of Variance (ANOVA)</u>

In this testing procedure the total variance in a set of data

was analyzed by breaking it down into its component sources which can be attributed to various factors in the research. One determines statistical significance of each of these factors by expressing the variance attributed to it as a ratio to the estimated sampling variance of the data. This is accomplished by means of the F test which can be stated as:

$$F = \frac{\text{variance due to factor X + sampling variance}}{\text{sampling variance}}$$

If the variance due to factor X is small then the F ratio will be small. On the other hand, if the F ratio is large, factor X accounts for a large part of the total variance in the data.

The simplest form of Analysis of Variance (ANOVA) is the one-way model which was used with simple random samples, to compare the impact of a single independent variable on the dependent variable. The case in which samples are of equal size and the fixed-effects model was assumed for purposes of simplification was considered. The ordinary output (F ratios) provided by SPSS subprogram ANOVA assumes the fixed-effect model. With the fixed-effects model we assumed that the test treatments were not randomly selected from a larger population of test treatments. Because of this assumption the test results cannot be generalized to other levels of treatment.

In one-way analysis of variance we can think of the value of a specific dependent variable measurement as being made up of three

parts: the grand mean of all observations, the treatment or IV effect, and random error. This three part partition can be expressed as:

$$X_{ij} = \mu + C_j + e_{ij}$$

in which

X_{ij} = the observation in row i, column j

C_j = the column or treatment effect in column j

e_{ij} = random error or sampling effect.

The total variance (SS_T) can be broken into two components representing the last two items of the above equation. These components are usually referred to as "between columns" variance (SS_K) and "within columns" variance (SS_W). The former represents the effect of treatments while the latter represents the remaining variance. While the latter is called "sampling variance," it includes all other unindentified forms of variance.

The procedure for the one-way ANOVA was as follows: (See Appendix H)

1. Hypothesis:

H_o: There is no significant difference in requirements spares computations variance between the two computational methods

H_1: There is a significant difference in requirements spares computations variance between the two

computational methods.

2. Significance Level:

$\alpha = .05$

3. Find Calculated Value:

$$F = \frac{\text{between-groups mean square}}{\text{within-groups mean square}}$$

4. Find Critical Test Value

5. Decision Rule:

If: Calculated F $\leq$ critical value, then select H_o

If: Calculated F > critical value, then reject H_o

This chapter presented the research methodology employed in comparing the two initial requirements methods in the SAIP program. After a decision of what type of test to use and if the data exhibited normal distributions, a statistical analysis was presented whereby the mean values and their variances could be evaluated and compared. The findings from this statistical analysis along with the conclusions and recommendations are presented in the next chapter.

Chapter 4

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Findings

After performing statistical analysis on the two SAIP computational methods, "MODMET" and "57-27," two significant findings were deemed pertinent to the research. First, the results of the SPSS t-test program showed a significant difference between the mean values of the two methods. That is, the recommended spares quantities for each NSN differed, with an overall significance. The "MODMET" computational method had the lower mean value, thus it can be concluded that it is a closer estimate to the actual demand for spare parts. Secondly, from the results of the SPSS ANOVA program, it was concluded that the "57-27" computational method has a slightly lower variance around its mean. See Appendix C for statistical results.

These results mean that when the "57-27" requirements computational method was utilized in requirements computations for spare parts, the estimated number of parts needed varied little but were always higher than the actual demand for that spare part. On the other hand, when using the MODMETRIC method, the estimated

number of parts needed varied slightly from the actual demand but these estimates were still closer to the actual demand than the estimate "57-27" provided.

Therefore, the MODMETRIC computational method proved to be statistically more accurate in estimating the SAIP spares requirements in the initial year of operation for the A-10 than the "57-27" method.

Conclusions and Recommendations

The importance of maintaining a wing or squadron of aircraft at the required operational state of readiness is critical to the U.S. deterrence policy. Additionally, accomplishing a state of operational readiness within directed budget guidelines creates a complex management burden. SAIP offers an initial and follow-on spares ordering technique which can ease this burden by ordering high dollar value spares concurrently with production and thus accruing a large price break than if the spares were ordered after the production line has closed. However, accurate quantities of spares must be ordered or the value of the program is diminished. If too many spares are initially ordered, then of course the operational readiness of the squadron will be enhanced, but investment, inventory, and obsolescence costs may outweigh the benefits received from readiness. On the other hand, if too few spares are initially ordered, operational

readiness may suffer and additional costs will be incurred when the Item Managers must eventually order a replacement spare or spares from the contractor. When a spare is ordered out of cycle, that is if the production lines must be interrupted or retooled, then the price of the spare will naturally be much more than if ordered concurrently with production.

Having examined the SAIP program for the A-10 aircraft, the conclusion was reached that the MODMETRIC computational requirements method provided more accurate results (closer to actual demand) than the "57-27" method which can also be used for SAIP computations.

It should be noted that a computations model may prove not to be a good indicator of actual demand based on many external factors. First, the IM must rely on contractor furnished data elements, such as estimated MTBF, for spares which have no historical records. If the contractor data later appears as inaccurate, then the original computation estimate will be inaccurate. Secondly, if the number of projected flying hours for the weapon system program changes drastically, then the spares estimate will again prove to be inaccurate.

That MODMETRIC proves to be a better indicator of spares requirements for SAIP should not be a surprise. By program design, SAIP is comprised of high cost, recoverable items specifically LRUs and their subassemblies, SRUs. The MODMETRIC program has as its

objective, to minimize the expected back orders of LRUs subject to an investment constraint on the total dollars allocated to both the LRU and its components. In contrast to "57-27," MODMETRIC explicitly considers LRU/SRU relationships. Specifically, it is assumed that no more than one SRU failure causes the failure of the LRU. Of course this assumption may not be totally realistic, it is a closer approximation to the modular design concept of today's weapon systems than "57-27" assumes. Basically, then MODMETRIC provides a more detailed description of Air Force recoverable item relationships than is provided by "57-27."

Based on the results of this research effort, a recommendation that the IM/SM utilize the MODMETRIC method of computing initial requirements for SAIP programs may seem appropriate. However, this research effort was predicated strictly on the A-10 SAIP application. It is recommended that further research, duplicating the methodology within this thesis, be conducted on other weapon systems utilizing the SAIP concept. If it can be conclusively proven that MODMETRIC more accurately predicts the demand for spares during the initial year of operation for a variety of weapon systems, then that method should be adopted as standard SAIP provisioning procedure. This action would then provide a standardized approach to computing requirements for SAIP recoverable items and can result in accurate fill rates and not extensive support costs.

APPENDIX A

AFLC FORM 614, RECOVERABLE ITEM

REQUIREMENTS COMPUTATION

WORKSHEET

RECOVERABLE ITEM REQUIREMENTS COMPUTATION WORKSHEET (INITIAL-REPLENISHMENT)

PREPARING ACTIVITY	BUDGET CODE	DATE
	BP-16	

I. ITEM DATA

1. NSN/NC & PART NO	2. Contractor & Registry Control No.	3. Noun	4. Contract Item Seq No.
1650 00604 6580	Bendix 4272	Valve	376

5. End Article	6. QPA-QPEI	7. Unit Price	8. U/I	9. ERRC	10. INS(1): 11 NSO(S)	11. FMC	12. AERNO
B-1	1	$450.00	EA	XD2	—		—

13. Lead Time A. Admin	B. Prod	C. Proc	14. Repair Cycle A. Base	B. Depot (1) Days	B. Depot (2) Mos	15. AFLC FORMS 22/29 135 781 A. C&ST	B. AVG MO PROG (1) OIM	(2) DLM	C. S/L PROG (PK)	D. No. Users	16. Similar Item NSN Part No.
3	15	18	6	56	1.86	14	15	—	30		

II. BASE PERIOD DATA

17. Base Period Prog	18. Base Rep Gen	19. Condemnations A. Base	B. Depot O/H	C. Total	20. Depot Repaired	21. Base NRTS
—	—	—	—	—	—	—

III. RATES AND PERCENTAGES

22. Cond % A. Base	B. Depot	23. Process % A. Base	B. Depot	24. Demand Rates A. Total OIM	B. OIM Depot	C. Base Rep Rate	25. W/O %	26. W/O Rate	27. NJR Repair Percent A. ENG O/H	B. PDM	C. MRS
0	.00	.50	.50	.4570	.2290	.2280	.10	.0230			0

28. NJR Repl %/JR W/O %	A. ENG O/H	B. PDM	C. MRS	29. O/H Rec %	30. Assets as of Date: A. Serv	B. Not Unserv	C. WRM	D. On Order	E. In Process	F. Total
(1) Repl			0	.2	—	—	—	—	—	—
(2) W/O			.2							

IV. BUY/OPERATING REQUIREMENT

Program Segment	A. Program	B. Rate	C. Requirement	D. $ Value
31. Update (REPLEN)				
32. OPERATING (REPLEN) PROC CYCLE/SL(INITIAL)	3 x 15 = 45	.0230	1.0	
33. Lead Time	18 x 15 = 270	.0230	6.2	
34. Depot Repair Cycle	1.86x15 = 27.9	.2290	6.4	
35. DEPOT SAFETY LEVEL (REPLEN)				
36. Base Repair Cycle	.20 x 30 = 6	.2280	1.4	
37. Base O&ST	.47 x 30 = 14.1	.2290	3.3	
38. Base Safety Level (REPLEN)				
39. Base Stock Level			4.7	

V. REPAIR REQUIREMENT – ENG OVHL MRS PDM

Program Segment		A. Program	B. Rate	C. Requirement	D. $ Value
40. Update (REPLEN)	JR				
	NJR				
PROC CYCLE/SL (INITIAL) 41. OPERATING (REPLEN)	JR	2 x 3 = 6	.20	1.2	
	NJR				
42. Lead Time	JR	2 x 18 = 36	.20	7.2	
	NJR				
43. Depot Repair Cycle	NJR				
44. Stock Level	JR	2 x 12 ÷ 30 = .8	.20	.2	
	NJR				
45. Floating Stock					

VI. ADDITIVES

46. WRM				
47. Other				

VII. REQUIREMENTS SUMMARY

48. Total Requirements	26.9	
49. Total Assets	0	
50. Net Procurement Requirement	27	$12150.00

AFLC FORM APR 75 614 PREVIOUS EDITION WILL BE USED

APPENDIX B

"MODMET"--"57-27" DATA SETS

100	ACTUAL DEMAND	MODMETRIC	57-27	"MODMET"	"57-27"
110	38	42	47	4	5
120	52	56	60	4	4
130	86	86	81	0	5
140	26	26	29	0	12
150	22	25	25	3	3
160	7	10	12	3	5
170	11	8	12	3	1
180	21	20	18	1	3
190	8	10	12	2	4
200	12	14	18	2	6
210	31	30	36	1	6
220	4	4	5	0	1
230	9	12	14	3	5
240	32	34	35	2	3
250	4	8	6	4	2
260	23	24	28	1	5
270	19	22	25	3	6
280	11	12	14	1	3
290	0	4	5	4	5
300	14	12	10	2	4
310	22	25	29	3	7
320	36	38	32	2	4
330	11	13	10	2	1
340	31	36	40	5	9
350	21	25	26	4	5
360	26	29	32	3	6
370	22	25	27	3	5
380	5	8	10	3	5
390	23	25	30	2	7
400	21	15	18	6	3
410	5	5	8	0	3
420	8	10	13	2	5
430	18	16	15	2	3
440	9	14	15	5	6
450	29	30	35	1	6
460	5	9	12	4	7
470	0	0	1	0	1
480	27	32	28	5	1
490	16	12	10	4	6
500	4	15	12	11	8
510	50	58	46	8	4
520	38	34	31	4	7
530	19	22	24	3	5
540	19	18	16	1	3
550	26	24	20	2	6
560	11	13	15	2	4
570	14	16	10	2	4
580					

APPENDIX C

STATISTICAL TEST RESULTS

The following is a summary of the results obtained from the statistical analysis performed upon the "MODMET" and "57-27" data.

1. The results of the K-S Goodness of Fit test led to the conclusion that the distributions are normal. Test statistics and appropriate critical values can be found in Appendix D.

2. From the results in Appendix G of the SPSS program t-test (independent samples), the one-tailed probability value of 0.00 was less than the α value of .10. This led to the acceptance of H_1: $\mu_1 \leqq \mu_2$. Accepting H_1 concludes that the "MODMET" computational method was significantly better than "57-27."

3. The SPSS ANOVA program resulted in a calculated value of $F = \frac{64.7239}{3.9672} = 16.315$, (d.f.=1,9[illegible]) and a critical test value of $F = 3.92$. Since the calculated value of 16.315 is greater than the critical value of 3.92, H_o was rejected and a conclusion was reached that based upon the results there is a difference between spares requirements computation variance between the two computation methods "MODMET" and "57-27." Looking at the values of standard deviation in Appendix H we see that Group Z "57-27" has a lower variance around the mean.

APPENDIX D

KOLMOGOROV-SMIRNOV GOODNESS OF FIT TEST

Decision Rule:

If: K-S Z $\leq$ Critical value of D, then select H_o

If: K-S Z > Critical value of D, then reject H_o

	Data Set	Sample Size	K-S Z	Critical Value of D	Conclusion
(1)	MODMET	47	1.133	1.22	H_o
(2)	57-27	47	.971	1.22	H_o

APPENDIX E

KOLMOGOROV-SMIRNOV GOODNESS OF FIT TEST--"MODMET"

FILE NONAME (CREATION DATE = 03/29/80)

- - - - - KOLMOGOROV - SMIRNOV GOODNESS OF FIT TEST

SATS
TEST DIST. - NORMAL (MEAN = 2.8085 STD. DEV. = 2.0709)

CASES	MAX(ABS DIFF)	MAX(+ DIFF)	MAX(- DIFF)
47	0.1653	0.1653	-0.1141

K-S Z	2-TAILED P
1.133	0.153

APPENDIX F

KOLMOGOROV-SMIRNOV GOODNESS OF FIT TEST--"57-27"

```
K-S GOF TEST(NORMAL)                                                         03/24/80        PAGE    1

FILE    NONAME    (CREATION DATE = 03/24/80)

- - - - - KOLMOGOROV - SMIRNOV GOODNESS OF FIT TEST

      DATA
TEST DIST. - NORMAL (MEAN = [illegible]        STD. DEV. =       [illegible])

            CASES       MAX(ABS DIFF)      MAX(+ DIFF)      MAX(- DIFF)
               67             0.11816           0.06062         -0.11816

            K-S Z           2-TAILED P
            0.971              0.302
```

APPENDIX G

T-TEST OF INDEPENDENT SAMPLES

T-TEST(INDEPENDENT SAMPLES) 03/29/80 PAGE 2

FILE NONAME (CREATION DATE = 03/29/80)

- - - - - - - - - - - - - - - - - - T - T E S T - - - - - - - - - - - - - - - - - -

GROUP 1 - COMP EQ 1.
GROUP 2 - COMP EQ 2.

VARIABLE		NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	F VALUE	2-TAIL PROB.	POOLED VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.	SEPARATE VARIANCE ESTIMATE T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
PARTS	DIFF. IN NO. OF PARTS												
	GROUP 1	47	2.8085	2.071	0.302	1.18	0.584	-4.04	92	0.000	-4.04	91.40	0.000
	GROUP 2	47	4.4681	1.909	0.279								

APPENDIX H

ANOVA FOR "MODMET" AND "57-27"

ONEWAY [illegible]
[illegible] (CREATION DATE = [illegible])

VARIABLE [illegible]

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	[illegible]	[illegible]	[illegible]	[illegible]
WITHIN GROUPS	92	[illegible]	[illegible]		
TOTAL	93	[illegible]			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
GRP01	47	[illegible]	[illegible]	[illegible]	0.	[illegible]	[illegible]	TO	[illegible]
GRP02	47	[illegible]	[illegible]	[illegible]	1.0000	[illegible]	[illegible]	TO	[illegible]
TOTAL	94	[illegible]	[illegible]	[illegible]	0.	[illegible]	[illegible]	TO	[illegible]
FIXED EFFECTS MODEL			[illegible]	[illegible]			[illegible]	TO	[illegible]
RANDOM EFFECTS MODEL			[illegible]	[illegible]			[illegible]	TO	[illegible]

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE [illegible]

TESTS FOR HOMOGENEITY OF VARIANCES

COCHRANS C = MAX. VARIANCE/SUM(VARIANCES) = [illegible], P = [illegible] (APPROX.)
BARTLETT-BOX F = [illegible], P = [illegible]
MAXIMUM VARIANCE / MINIMUM VARIANCE = [illegible]

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